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# EVIDENCE FOR A 17-DAY PERIODICITY FROM Cyg-X-3

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EVIDENCE FOR A 17d PERIODICITY FROM Cyg X-3

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Cyg X-3 (3U 2030+40) has exhibited phenomena which are observationally unique among identified x-ray sources. The giant radio flare of 1972 is, perhaps, the most spectacular such anomaly, but there are others no less unusual. A wide variation in x-ray spectra has been observed, including the identification of x-ray emission lines at some times, and consistency with a black-body at others.<sup>1</sup> The  $\sim$  sinusoidal 4.8h variation<sup>2</sup> is at a period far in excess of any rotation period which has been ascribed to the compact members of other binary sources, and at least four times shorter than any comparable orbital period. Models have been constructed which identify the 4.8h variation with orbital period<sup>3,4,5</sup>, acknowledging the peculiar geometries which could give rise to a smooth 4.8h effect in observed x-rays. The present data indicate that a much longer periodicity of  $\sim 17$ d is also characteristic of Cyg X-3.

The Ariel-5 All-Sky Monitor, from which most of the present data are taken, has been described in detail elsewhere<sup>6</sup>. The important parameters are an effective pinhole area of  $0.6\text{cm}^2$  in the energy band 3-6 keV, an average duty cycle for source observation of  $\sim 1\%$ , and no temporal resolution finer than 100 min. Typically,  $\sim 10$  Cyg X-3 counts are accumulated each 100 min. orbit in a resolution element of spatial dimensions  $\sim 10^\circ \times 10^\circ$ , with a background of  $\sim 2$  counts.

Figure 1 is a useful verification of experiment performance on Cyg X-3. Single-orbit data from  $\sim 100$  days are plotted modulo 4.8h from Cyg X-3 and, as a control, Cyg X-1 (with which it might conceivably

be confused with resolution elements centered  $\sim 10^\circ$  apart). Data points are accepted only if they represent an unambiguous determination of source intensity (i.e. there is less than a 10% possible contribution from other sources, and the intensity is at least twice the estimated one-sigma error after all corrections have been applied). In folding, the data from each 100 min. accumulation are tagged with the orbit midtime. Each bin in Figure 1 is statistically independent from the others, as an orbit contributes to only the bin that contains its midtime (even though the data are accumulated over the equivalent of 3-4 bins). The smooth light curve obtained for Cyg X-3 is not, therefore, an artifact of the folding procedure. Both the shape (and phase) are in excellent agreement with the results of ref. 7, indicating that the present measurements are consistent with their period (and error) of  $0.1996811 \pm .0000016d$ .

Additionally, there is considerable variability in the day-to-day intensity of Cyg X-3, as evidenced by Figure 2. This behavior is in marked contrast to the constant (within the relatively poor statistics) day-to-day nature of Cyg X-1 measured simultaneously with the same experiment<sup>8</sup>. There is, however, some indication of regularity in the Cyg X-3 variations, as illustrated in Figure 3. As the Cyg X-3 data from individual orbits do not always satisfy the  $2\sigma$  condition, the All-Sky Monitor data used in both Figures 2 and 3 are derived from  $\sim \frac{1}{2}$ -day accumulations which are then analyzed in exactly the same way as are the individual orbits. It is not possible to unambiguously compensate completely for the 4.8h variation in the construction of

these Figures, so that no attempt has been made to do so. This variation, as well as gaps in the finite data string and an apparently erratic source behavior, result in many periods in excess of a few days which give relative  $\chi^2$  maxima (9.5d, 14.5d and the 15.7d exhibited in Figure 3 are among the more pronounced maxima). The 17d effect is not only the most significant statistically, but also exhibits a roughly symmetrical  $\chi^2$  distribution which has a width commensurate with the length of the data sample. On the basis of Figure 3 alone, we would estimate a period of  $16.9 \pm .3d$  and a phase at maximum of JD 2,442,387.5 $\pm$ 2 near the most pronounced peak of Figure 2, where this phase is estimated from the peak in the total data string folded at 16.9d.

Figure 2 also contains data from the Ariel-5 Sky Survey Experiment against which the 17d hypothesis may be tested. It is important to note that the latter measurements are obtained in the gaps of the All-Sky Monitor coverage, as the two experiments possess mutually exclusive fields-of-view. All the data are generally consistent with the displayed grid of 16.9d, but it is clear that the effect is not completely reproducible. Almost all of the apparent maxima fall relatively close to the grid, but they are not always clearly defined (and are sometimes absent).

We have attempted to test the 17d hypothesis with older data in the literature, with inconclusive results. Ref. 1 contains a point measurement of high intensity (JD 2,441,959.65) and one of low intensity (JD 2,442,323.71) just prior to the commencement of Ariel-5 operation.

Older relatively high intensity measurements from UHURU<sup>7</sup> are JD 2,440,988.5 and JD 2,441,450.0. A period of 17.05d, at the phase determined by the All-Sky Monitor folding, results in all three historical "maxima" falling at a phase within  $\pm .05$  of the expected maximum centroids, while the "minimum" falls more than 0.3 away. In view of the fact that the present maxima are not as precisely locatable (the times of the older measurements are determined by the reported midtimes of the observations only), we expect that this agreement is fortuitous. It would appear that the reality of the 17d effect can be tested only by continuous observation over another year or so.

In Ref. 1, the authors point out that the "high intensity state" of Cyg X-3 is relatively well-fit by a structureless black-body, in contrast to the considerably more complex spectra observed in lower intensity states. They further suggest that the total source luminosity is close to Eddington-limited, and approximately constant regardless of spectral form. This interpretation of "high intensity state" is, therefore, a manifestation of the relatively better efficiency of contemporary experiments near the black-body peak than at higher energies. We are assuming here that this interpretation is correct, and that the times of Cyg X-3 maximum correspond to increased electron scattering in the source.

One possible explanation would arise naturally if the 17d effect was the orbital period of the binary system containing Cyg X-3. In this case, however, the stability of the 4.8h variation (which would now be interpreted as a slow source rotation) would seem to severely

constrain this hypothesis. No apparent 17d Doppler variation in the 4.8h modulation is detectable in the present data ( $v_x \sin i < 300$  km/sec), and it is difficult to account for the long-term stability of this period unless the surface field is much lower than that expected if the observed 4.8h modulation arises from rotation.

A less drastic suggestion (i.e. one which does not alter the identification of 4.8h with the orbital period) is that the 17d effect is analogous to the 35d variation in Her X-1 (c.f. ref 9). The consistency of both Cyg X-3 and Her X-1 with contact-binary models (in contrast to the supergiant-stellar-wind models reconcilable with the mass source in other identified x-ray binaries) makes this conjecture attractive. It is interesting to note that the interpretation of this effect in terms of free precession<sup>10,11</sup> does not necessarily require a neutron-star source for Cyg X-3 just because the 17d and 35d time-scales are comparable. A precession period of 17d is entirely consistent with either a neutron star with rotation period  $\sim 1$  sec, or a white dwarf having a rotation period of the order of minutes. Its interpretation in terms of the precession of the primary member of the binary system (c.f. ref. 12) is likewise insensitive to the nature of the secondary. While it does not appear that the 17d effect can unambiguously distinguish between a white dwarf and a neutron star, the inferred high luminosity and relatively hard spectrum out to  $\sim 40$  keV would seem to favor the latter.

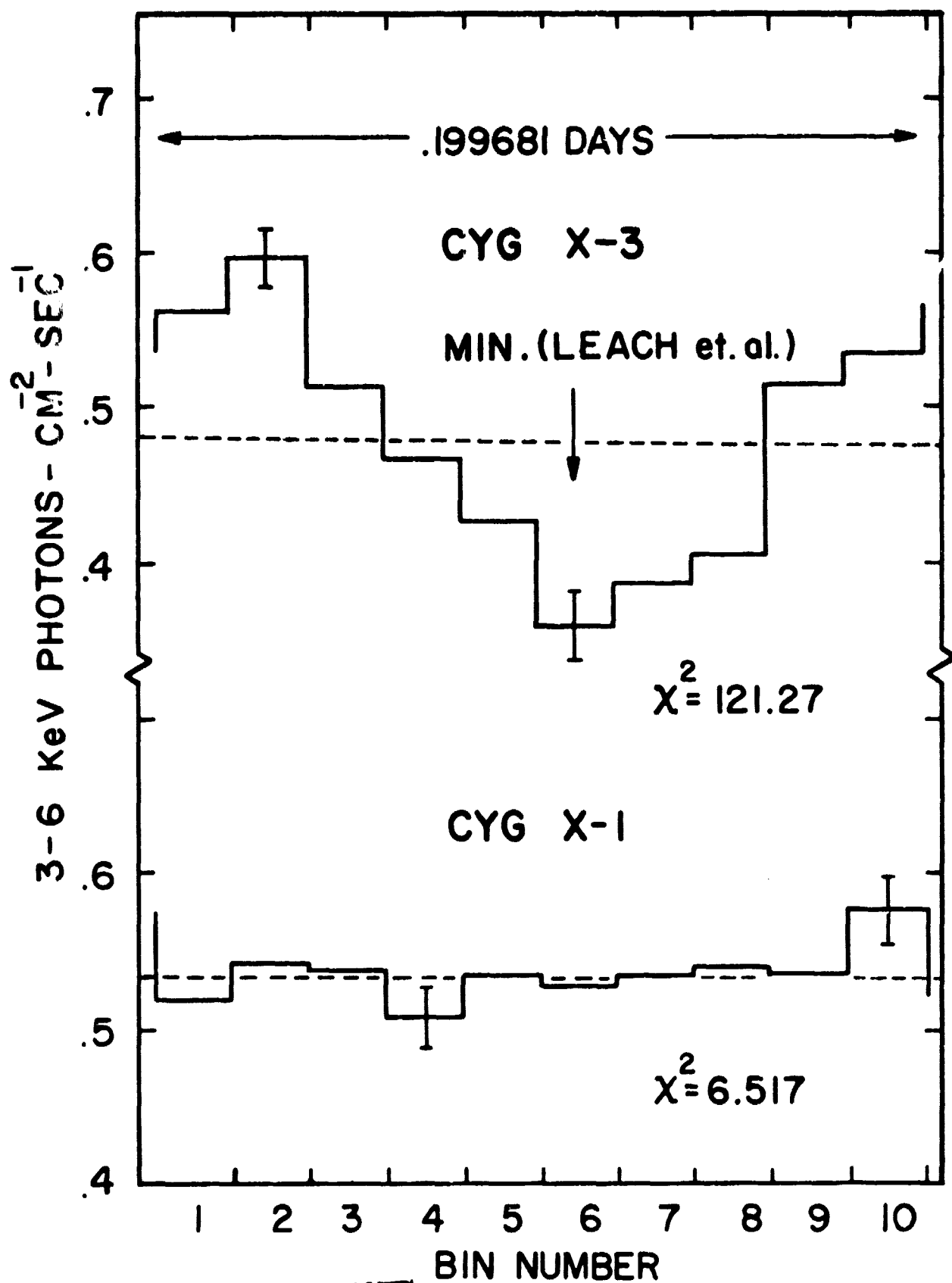


## Figure Captions

1. Approximately 100 days of single-orbit Cyg X-3 and Cyg X-1 All-Sky Monitor data obtained between December 1974 and March 1975 folded at the Cyg X-3 period (with indicated phase) of ref. 7. The indicated  $\chi^2$  values are for 10-bin folds (9 degrees of freedom) against the hypothesis of a constant source intensity.
2. Continuous record of Cyg X-3. The data points are daily averages of All-Sky Monitor data, with  $\pm 1\sigma$  error bars. The shaded bars are  $\pm 1\sigma$  thick, 1.6d averages of Sky Survey Experiment data. These latter are 2-18 keV measurements which are normalized to the natural All-Sky Monitor ordinate with the response of both instruments to the Crab Nebula. The grid above the data indicates the positions of expected maxima with the best fold values of period (16.9d) and maximum (JD 2,442,387.5).
3.  $\chi^2$  obtained by folding the All-Sky Monitor data at 0.1-d intervals between 15 and 19 days in 10 bins, against the hypothesis of a constant source intensity. The two traces correspond to the same data folded at two different binning phases (i.e.  $\frac{1}{2}$ -bin out of phase at 16.9d). As in Figure 1, Cyg X-1 data similarly folded did not yield any significant values of  $\chi^2$  near the Cyg X-3 maximum.

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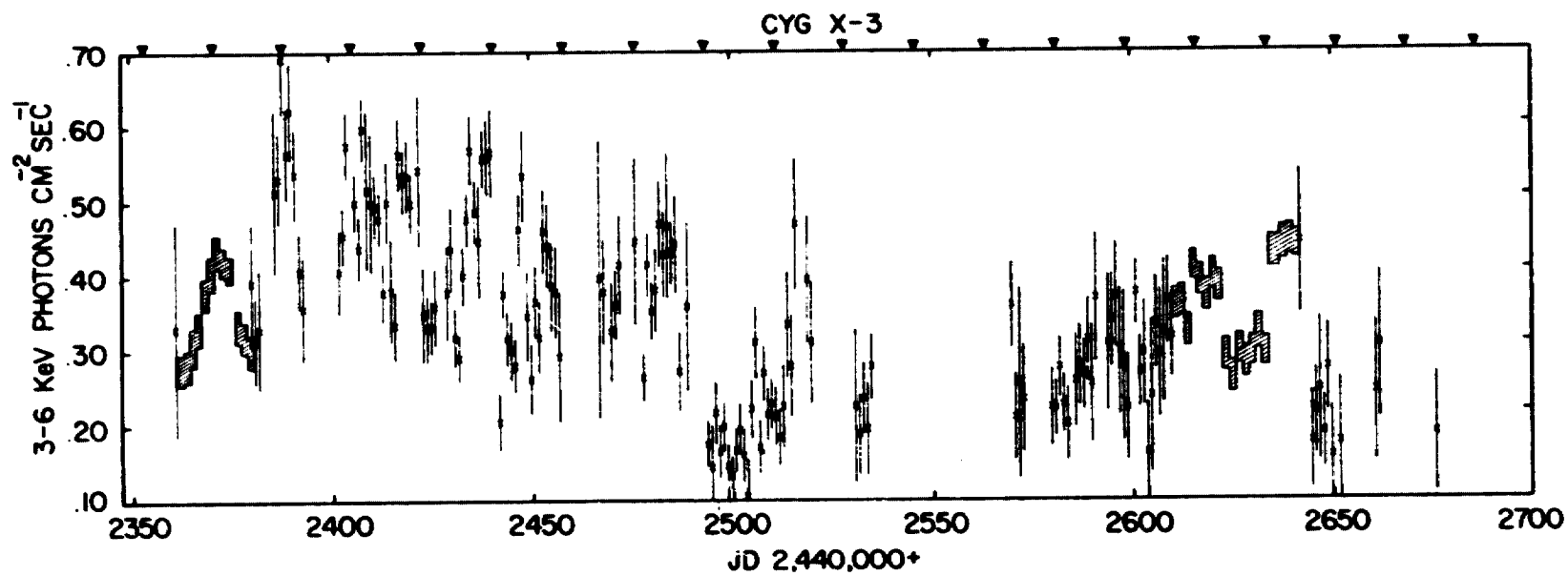


Fig. 2

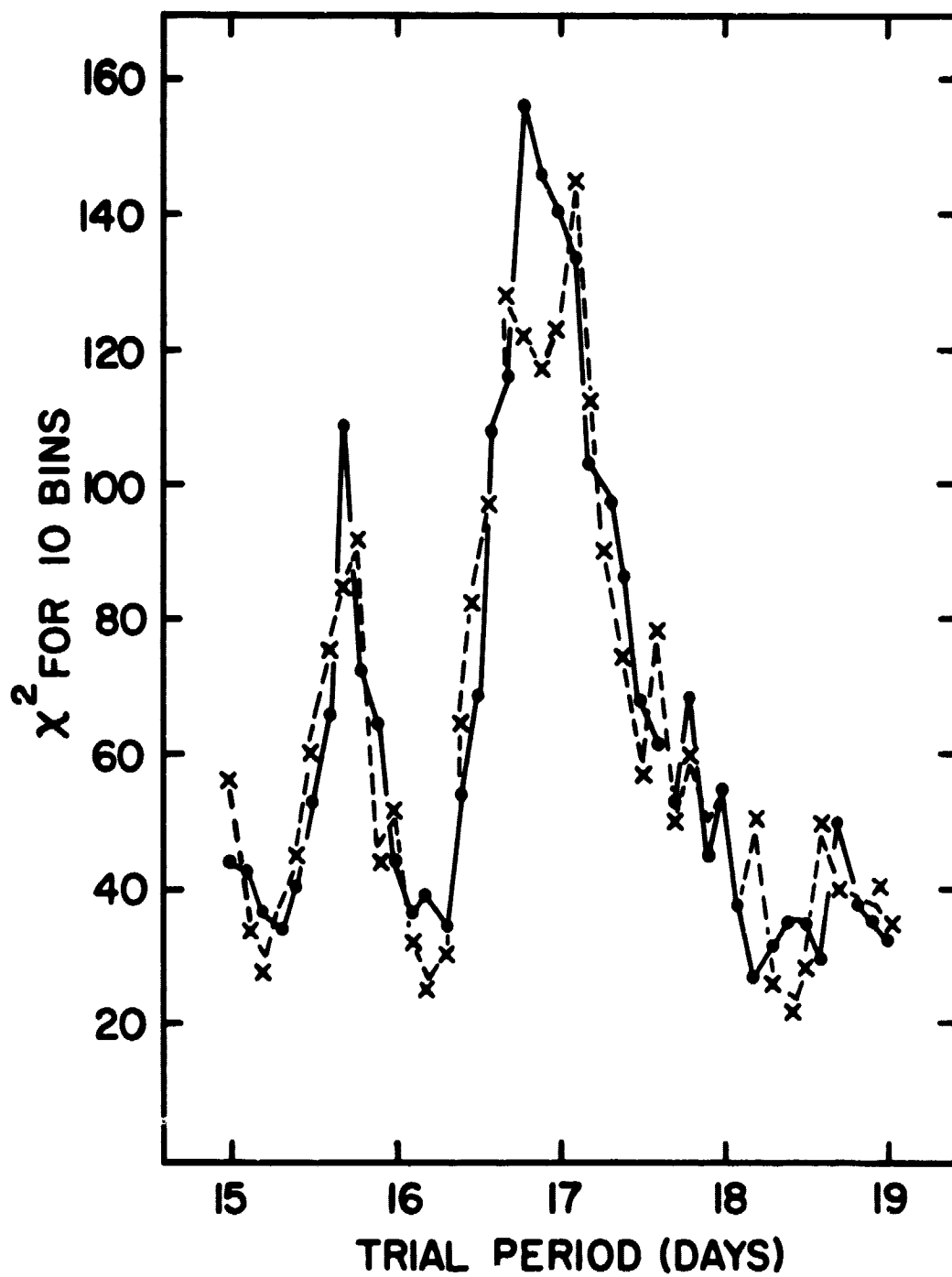


Fig. 3